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Offshore coral reefs in the South China Sea: science, problems, and solutions

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A turnaround at Sanya National Coral Reef Nature Reserve?

Austin H Yeung, David M. Baker

Abstract This paper examines efforts by the scientific community, the media and the regulatory bodies, respectively, in researching, reporting and managing the Sanya National Coral Reef Nature Reserve on Hainan Island, China's first national-level marine protected area (MPA) dedicated solely to coral reef protection. Due to rising economic needs of Sanya's tourism-dominant economy, heightened public awareness, and renewed prioritization by central and local governments, a turnaround is underway. Through this paper, we depict how science informs policy making and influences efforts in reef protection, and how media reporting raises awareness and documents a possible turnaround. For Sanya, environmental protection has become a top priority due to the mandate of the Central Government's Five Year Plan, and the approach, taken by local authorities to balance development and conservation, is lending support to new optimism. In conclusion, it is suggested that more efforts are needed to monitor marine conservation and protection, understand spatial distribution and coverage of corals, and decipher past and present baseline conditions of coral reefs, such as age, biodiversity and health status of past, existing, and restored reefs.

Keywords: MPAs, coral, Sanya Marine Reserve

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Introduction

In China, marine protected areas (MPAs) are classified at the national or local level,

depending on whether the lead administrative duties rest with the central (national) or the local (provincial and city) authorities. China MPAs are also classified as Marine Nature Reserves (MNRs) and Special Marine Protected Areas (SMPAs) in accordance with their dominant functions (e.g. conservation of antiquity or natural resources), natural attributes, and social requirements. China MNRs are generally considered more ‘protected’ and prestigious, whereas China SMPAs have less restriction to access and may include ocean parks and other integrated coastal management zones. While marine reserves around the world are often considered no-take zones, this is not the case in China where nature reserves are so designated to protect specific species, e.g. coral reefs or Chinese white dolphin; but fisheries, tourism and other extractive activities are often not prohibited.

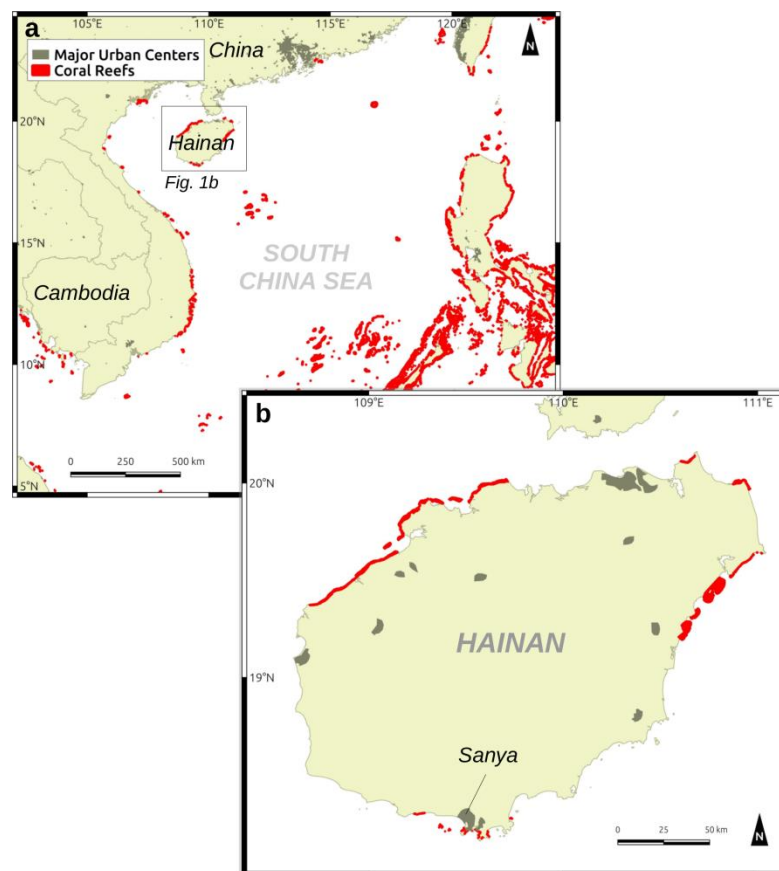


Fig. 1 Location of Sanya, Hainan province, China

With over 14,500 km of coastline, and 6,900 islands having $>500 \text{ m}^2$ surface area, China first made a concerted effort to create MPAs in the 1990s, although Bohai's Snake

Island was reportedly the first to be recognized a ‘protected area’ in 1963 (Zeng 2013). Since then, China has designated a total of 221 MPAs, which include 157 MNRs (33 national and 125 local) and 64 SMPAs (28 national and 36 local), covering 33,000 km² of coastal and marine areas (Ma et al. 2013). Among all of China’s MPAs, the city of Sanya boasts the first national-level MNR solely dedicated to coral reef protection, the Sanya National Nature Marine Reserve (“Sanya Marine Reserve”). What makes it special yet challenging is the fact that Sanya Marine Reserve is the only marine protected area located directly within a well-known and high-traffic tourist city in Hainan province, at the northern part of the South China Sea (Fig. 1).

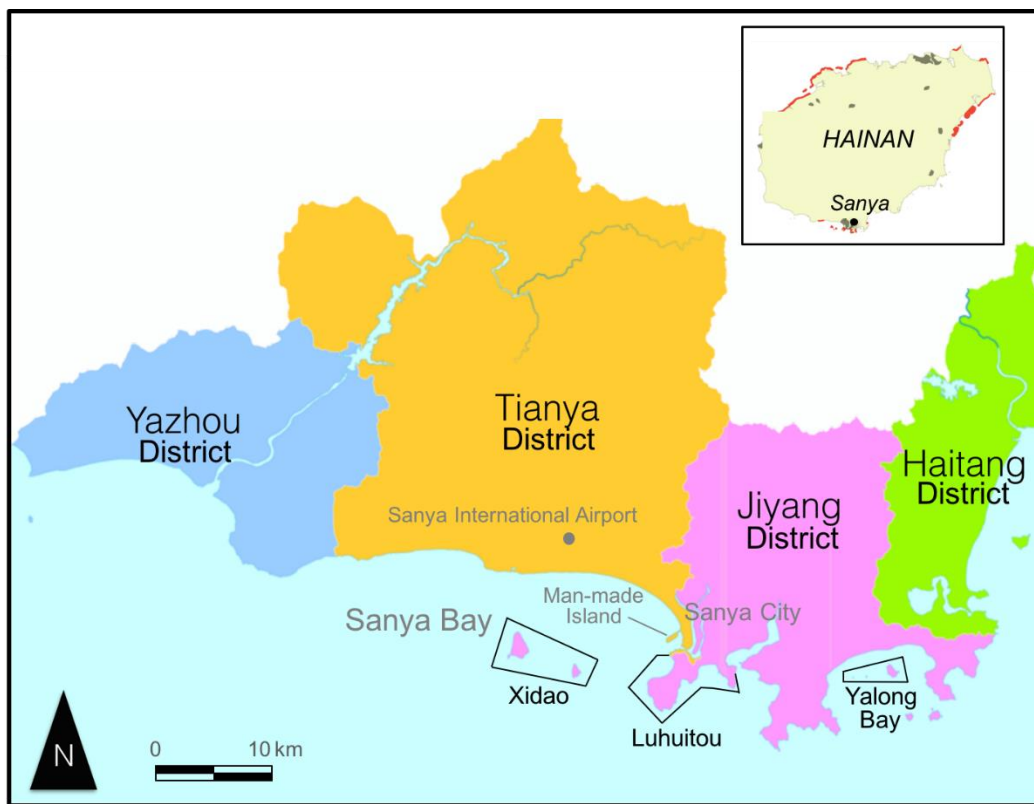


Fig. 2 Map of Sanya Marine Reserve. Source: Qiu 2013

Located midway along the coastline of Sanya City, lying between 109°21’ to 109°40’E and 18°10’ to 18°15’N, Sanya Marine Reserve has an official area of 56 km², of which about 50 km² are in coastal waters (Fig. 2). It is made up of three different regions spanning from Yalong Bay in the East, Luhuitou in the middle, and Xidao in Sanya Bay in the West. Officially, Sanya Marine Reserve has designated its conservation and management

practices based on three zones: core, buffer and experimental. No entry is permitted in the core zone, whereas research and scientific monitoring are allowed in the buffer zone. Within the experimental zone, fishing and extractive uses are prohibited, yet enforcement has not always been successful. Research, tourism, diving, and breeding of rare and endangered species are allowed in such experimental zones (Qiu 2013).

Coral monitoring and research - coverage, biodiversity and distribution

Coral coverage

In China, decades of unrelenting economic expansion have yielded the world's second largest economy, for which China's GDP has grown tenfold since 1978. During this period, many coastal cities doubled their local populations and saw 2-3 orders of magnitude increase in GDP. Sanya, China's only seaside tropical resort city, was no exception. Over the past 3 decades, Sanya's registered local population doubled to 750,000 while its GDP grew 200x, reaching 43.5 billion RMB in 2015 (Wang and Wang 2016). While such breakneck growth brings wealth and prosperity, it has also taken a toll on the environment and Sanya's marine resources, causing adverse after-effects on the coral reefs.

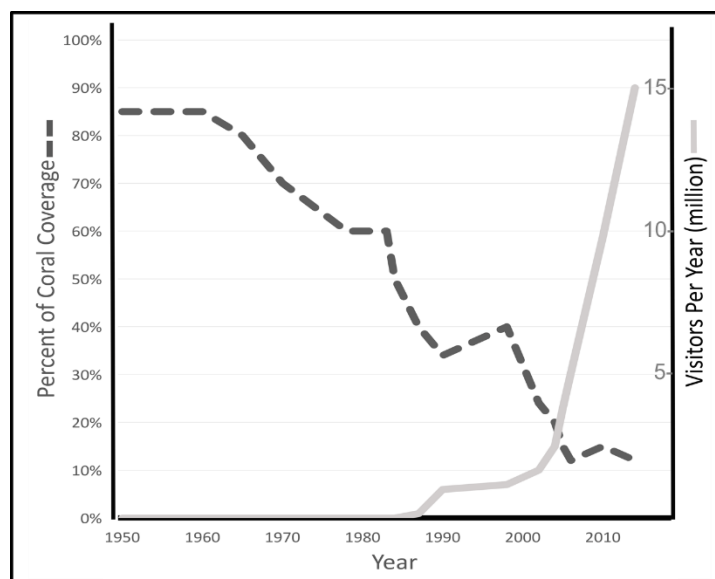


Fig. 3 Sanya Marine Reserve - Luhuitou coral coverage and Sanya City annual visitors. Sources: Zhao 2010 and Sanya Municipal Government 2013, 2014

Reports of such impact can be found in the coral research literature. For years, a number of international and Chinese researchers have been monitoring coral reefs at Sanya, and have reported declines in distribution, coverage, and biodiversity. Coastal fringing reefs at Luhuitou within Sanya Marine Reserve, for instance, have experienced overharvesting, pollution, habitat destruction, and other anthropogenic stresses that came with rapid economic growth, as illustrated by changes in coral coverage and the number of annual visitors to the tourism-dominant city of Sanya over the years (Fig. 3).

According to Zhao et al. (2010) the coral coverage at Luhuitou was at 80-90% in the 1960s and has fallen steadily in recent decades despite concerted efforts in conservation and protection. In 1960s -70s, destructive and overfishing activities, along with large-scale coral mining, were responsible for punctuated coral decline at Luhuitou fringing reefs. Starting in early 1980s, mariculture of pearl oyster and *Eucheuma* in coastal areas led to direct reef destruction, while prawn and abalone breeding farms contributed indirectly, yet significantly, to degradation of Luhuitou fringing reefs. As a result, coral coverage fell to 60% in 1978-83, and to 35% in 1990. Coral coverage recovered to 42% in 1998, perhaps due to temporary reprieve and protection afforded by Sanya Marine Reserve when it was first designated (Zhao et al. 2014). But coral coverage declined further to 23% in 2002, and to a steady level of 12-15% starting around 2006 (Zhao et al. 2008, 2012). Separately, surveys of Luhuitou fringing reefs by Zhao (2010) showed a dynamic change in live coral cover between 1998 and 2006, where coverage dropped from 45-70% in certain transects to 10-12% over the 8-year period. Other surveys (Zhang et al. 2006) confirmed a general declining trend from about 85% in the 1960s to 20% in 2004. Such declines since the mid 1990s had been attributed to loss of habitat and presence of acute stresses, such as a rise in sedimentation. In the meantime, tourism at Sanya began to pick up its pace; by 2015, the number of annual visitors to Sanya has reached 15 million, an increase of 100x over three decades (Fig. 3).

Biodiversity

In the 1960s, hermatypic corals of the Luhuitou coastlines included 12 families, 24 genera and 83 species; by the 1990s these corals had been reduced to only 10 families, 21 genera and 58 species (Zhang 2004). Zhang's data (2006) show concomitant declines in biodiversity and distinct spatial differences within the coral communities. Fewer coral species were found

on the reef flat than on the reef slope. Low coverage on reef flats was the result of human poaching and damage, especially at low tides during which the reef was more exposed. The result of sewage runoff, agriculture and mariculture pollution also played a role there.

Dominant species and genera; spatial distribution and extinction

Zhao et al. (2008) reported results from 84 quadrats along 5 vertical transects on Luhuitou fringing reef using video-quadrat methods. The results showed that *Porites lutea* was the most dominant species covering up to 44% of the area with *Acropora* species at 23%. Zhao et al. (2012) reported that, in the 1960s, the coral community structure in Luhuitou within Sanya Marine Reserve was divided into three well-defined zones: a *Goniastrea* zone and a *Montipora* zone, both on the reef flat, and an *Acropora* zone on the reef slope. However, by 2009, *P. lutea* was the dominant species on the reef flat, whereas the prevalence of *Acropora* on the reef slope dropped significantly.

Other studies also highlight the age and vulnerability of coral reefs to anthropogenic impacts. Approximately a third of hermatypic coral species have become locally extinct and more than 70% of coral colonies are less than 30 years old (Zhang 2004). The age structure of populations was determined through growth rates extracted from X-rays of *P. lutea* cores. The majority of colonies (>95%) were less than 50 years old, with 55% of *Porites lutea* on the reef flat having been recruited following the establishment of Sanya Marine Reserve in 1990. Nonetheless, the abundance of younger colonies indicated a significant recovery of *P. lutea* following the removal of chronic anthropogenic disturbances (Zhao et al. 2014).

Anthropogenic effects: pollution, habitat loss, and poaching

Pollution

In China, pollution is one of the leading disturbances to the environment. According to Wu and Zhang (2012), many coastal cities, including Sanya, lacked comprehensive sewage treatment systems as economic activities picked up and accelerated since the turn of the century. In 2004, for instance, 200 million tons of sewage and industrial waste were discharged, causing increased levels of pollution in 70% of rivers and lakes within China (Gorvett 2013). For coral reefs, sewage pollution and increased nutrient enrichment can

negatively affect coral health by increasing the macro algae growth rate-(Wear and Thurber 2015). Although much of the sewage or untreated wastewater was from urban development zones, rural dwellings contributed as well. Rural runoffs in the form of fertilizers and manure contaminated coastal waters (Shen 2015). Furthermore, fish, oyster and other shellfish farms were the main culprits from mariculture or aquaculture.



Fig. 4 Man-made island and land reclamation in Sanya Bay. Source: <http://dp.pconline.com.cn/photo/2020419.html>

Loss of habitat

Rapid development and coastline construction projects have been devastating Sanya's coral reefs (Shu 2012). Construction wastewater causes sporadic yet significant damages to reef ecosystems, not only as a result of pollution, but also loss of habitat. In Sanya Bay, a 474,000 m² man-made island (Fig. 4) was built through land reclamation in the direct vicinity of the Luhuitou region of Sanya Marine Reserve (Fig. 2). These projects not only transformed the coastlines of Sanya Bay, they drastically changed water quality and currents, and spatial distribution of coral reefs. Such construction projects, for instance, raised sediment levels and turbidity of the water, smothering living corals (Shen 2015). A number of coral colonies had been altered or destroyed (Sun 2015). Besides deterioration of spatial distribution of corals, increases in sedimentation had altered Sanya's coastal habitat (Kuang 2015).

Over-harvesting and environmental damage

In China, coral is a valuable art commodity. Coral heads have been sold as souvenirs and serve as a vital component of the curio trade. Both fishermen and hawkers sell fragments of coral and coral pieces on the beachfront and in shops around Sanya (Wu and Zhang 2012). In addition, Sanya local residents have a misconception that precious gemstones or the so-called “fossil jade” can be found within coral heads. This misbelief that jade can be found within coral is impossible, as the jade that locals often look for are a few million years old, while coral in Sanya have only been around for not more than several thousand years. “Jade harvesting” (Fig. 5) was one of the main causes of coral cover decline before the onset of tourism in the 1990s (Wang and Wang 2016) as locals flocked to the reefs to find treasure. Furthermore, damage could be attributed to poorly trained or careless divers, who are often unsupervised and tour operators unregulated. Indeed, many unlicensed dive shops and tour operators brought groups into Sanya Marine Reserve (Zhang 2010). Snorkelers and divers often have no concept of preserving the reefs. Local authorities have made attempts to curtail these destructive behaviors by imposing new regulations; yet, monitoring was poor, enforcement was inconsistent, and imposition of penalties or fines was rare.



Fig. 5 Coral mining in search of ‘million year old jade’. Source: Zheng and Wang 2011

Government administration and regulations

Like other MPAs in China, Sanya Marine Reserve has a three-tier regulatory structure for policy and management. At the national level, the State Oceanic Administration (SOA) is the

leading agency responsible for China's ocean policymaking and overall management of ocean and coastal affairs. It is responsible for drafting laws and regulations concerning sea area uses, environmental protection, and scientific research. Many MPAs are under the jurisdiction of the SOA. Other MPAs may be overseen by the State Environmental Protection Administration (SEPA). At the local level, there are two tiers of governance: for the provincial tier, the Hainan Provincial Oceanic Department is the regulatory body in charge of policymaking and administration with respect to Sanya Marine Reserve; for the city tier, Sanya Marine Reserve is managed by national coral reef natural protected area management office and by the City of Sanya, via its Marine and Fishery Department.

For the past fifty years, the government has tried to stem the tide of environmental destruction through its legislation, including laws that were passed to protect coral reefs. For example, in 1983 the State Law of Marine Environment Protection was issued as one of the earliest regulations in China. One year later, the Chinese central government declared 'environment protection' to be a fundamental national policy (Zhang 2004). For the protection and management of coral reefs, the State Law of Marine Environment Protection, and the State Management Regulation Preventing Coastal Engineering Projects from Marine Environmental Damage and Pollution were both enacted in 1993, strictly prohibiting coral destruction by any coastal engineering activities (Zhang 2004). In 1994, the SEPA introduced its China Biodiversity Protection Action Program, followed by the issuance by SOA of State Regulation of Natural Resources in 1994, and Rules of Marine Natural Reserves Management in 1995. National Standards for Marine Zones were released in 1997, and rules from State Technical Control Bureau in 1998.

On the provincial level, the Hainan Provincial Oceanic Department is the regulatory body in charge of policymaking and administration. In 1998, the Hainan government issued the Hainan Province Regulation of Coral Reef Protection act, which prohibits coral mining, blast and cyanide fishing, coral and shell collection, and the establishment of waste outflows into coral reef marine reserves (Gorvett 2013). On the local level, the Sanya city government also had issued a number of ordinances regulating tourism and coral reef resource uses to protect coral.

Yet even with local legislations that aim to protect and create jurisdictional and zoning boundaries, and allocate use rights for coastal and marine resources, drops in coral coverage and biodiversity continue.

A major reason for this continued decline is that outcomes in policy implementation have been mixed. The reality is that the SOA and SEPA have limited power in enforcing these policies at the local level (Cao and Wong 2007). Locally, performances of government officials have been measured in terms of GDP growth, meeting development targets, and job and tax revenue gains, not necessarily protecting the environment (Hughes et al. 2012). For these government officials, enforcement of protection laws was not a top priority. Structurally, there are also challenges as there is no legally mandated system of monitoring environmental changes at MPAs. Loss of coral cover as well as persistent declines in coral distribution and biodiversity are often unrecognized and unreported (Hughes et al. 2012). As mentioned earlier, travel tours were not regulated or monitored; many tour guides simply operated without licenses (Zhang 2004). As economic growth and tourism took flight at Sanya, environmental protection took a back seat - and the continuous destruction of Sanya's coral reefs has proved to be disastrous.

Recent development: heightened public awareness and media reports

However, in recent years a shift in focus seems to be happening. Citizen awareness has increased, as more frequent media reports have been noted, or are less censored. Government priorities are seen to be shifting from 'economic development only' to 'economic development *and* environmental protection'. For instance, student divers visiting Sanya had recognized the needs for conservation. They had called the visibility underwater there 'abysmal'. More colorful depictions from the locals and visitors include calling the water "Miso Soup", meaning practically no visibility. Media reports are also raising awareness. Reports from Hainan News and other media outlets are playing a vital role in effective education, awareness, and oversight. For instance, media reports have highlighted the plight of Sanya Marine Reserve, lamenting the limited resources there, with a staff of only six people overseeing the entire Sanya Marine Reserve (Feng and Ge 2015). Recently, poaching of coral heads was photographed and widely reported, prompting a formal and urgent

response from the regulatory authority - something unheard of in the past (Feng and Ge 2015).

Indeed, officials at the national level are aware of the ecosystem damages. It was reported that ecosystem damage costs China 9% of its GDP every year, and that China's economic boom has created severe environmental degradation (Gorvett 2013). This realization led to the deployment of further environmental policies. At the local level, Sanya and Hainan governments recognize the significance of their reef-based tourism industry on the local economy. For the past three decades, Sanya's economy has evolved from primary and secondary industries, such as farming and manufacturing, to tertiary industries such as tourism (Sanya Municipal Government 2014, Fig. 6). The importance of preserving natural resources cannot be overstated when 65% of Sanya's GDP is derived from tertiary industries (mostly tourism) as of 2015. It is now clear that the local government recognizes the importance of protecting the environment. In other words, being “environmental is good business.”

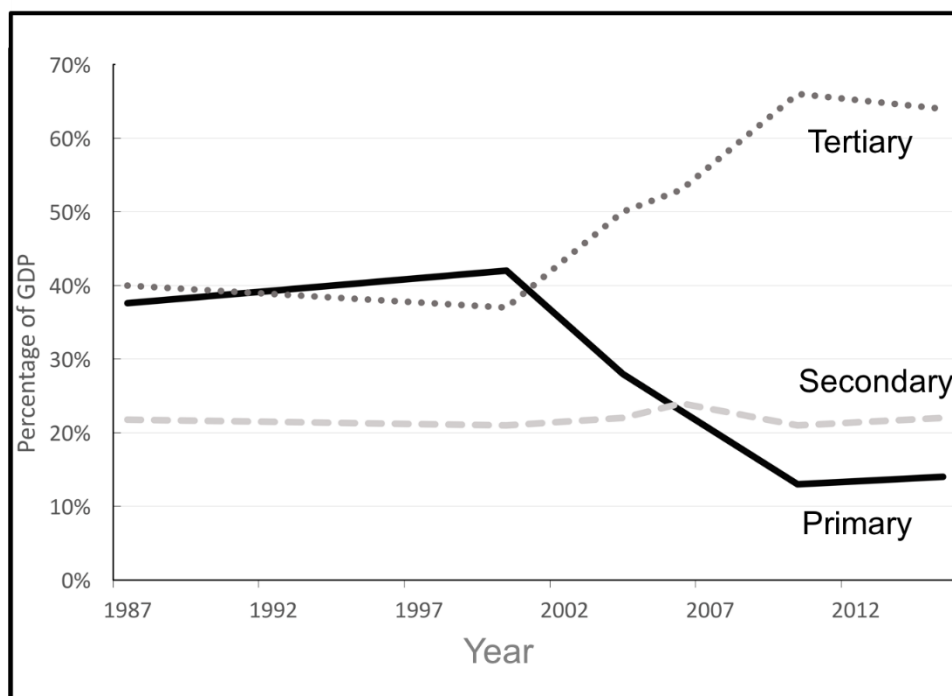


Fig. 6 GDP from primary, secondary and tertiary industries at Sanya. Source: Sanya Municipal Government 2014

Central government's five-year plan - conservation and management

In recent years, new policy making and enforcement actions have been taken by the central, provincial and city governments at Sanya Marine Reserve, as highlighted in Table 1. The most significant reason for positive changes in policy making has come from the central government as the focus of national priorities every five years have shifted to include more environmental aspects. In the 12th Five Year Plan of 2010-5, “Energy Saving & Waste Reduction” was included as a top priority for China. It aimed to promote energy and water efficiency, while also minimizing waster discharges and pollution. It is reinforced and enhanced within the 13th Five Year Plan covering 2016-2020. Such priorities in environmental protection are largely responsible for making local (provincial and city) government officials more accountable. No longer are local officials solely evaluated in terms of GDP growth and job creation. The “quality” of such growth, or the collateral damage that comes with such growth, is also assessed. On 20 August 2015, State Council of China announced its national plan for marine functional areas, with the intent to improve marine resource development and management, as well as protect marine ecosystems.

Among other measures announced was the proclamation that MPAs will be increased to 5% of coastal areas under Chinese jurisdiction to strengthen marine habitat protection. Preservation and protection of natural coastal environments is to be at least 35%. China Coast Guard is seen to be increasingly arresting illegal tour operators in Sanya Marine Reserve (Yang 2016a), and control of the outflow of pollutants and stabilizing water quality in coastal waters is now a top priority (Yang 2016b).

Through the Five-Year Plan, such policy actions from the central government are supporting conservation and management at the local level. Not only is the Hainan Provincial Regulation of Coral Reef Protection of 1998 now being more heavily enforced, the Hainan provincial government has issued a preliminary planning and zoning order that covers coastal land mass and coastal waters. The integrated approach, “Marine Ecological Red Zone District Policy” is a prime example of science informing policy making and resource management (Feng and Ge 2015). It is meant to ensure and protect ecosystem functioning, water works and waterways, forestry, and oceanic perspectives. This allows the provincial and city governments to coordinate activities on land and at sea -- thus balancing priorities.

Table 1: New policy making and enforcement actions by central, provincial and city governments at Sanya Marine Reserve

	Central Government	Hainan Provincial Government	Sanya City Government
Pollution Reduction	12-13th Five Year Plans – Energy Saving & Waste Reduction	Land-Sea Red Zone Policies: 11000 km ² land & 3000 km ² marine ecosystem zoning/mix uses	300M RMB earmarked for eco spending, incl. 150M RMB on waste water treatment plants; added 267km new pipeline for rainwater/wastewater dispensing
Habitat Protection	Targeting 5% MPA; 35% natural coastline	Tear-down of illegal or non-conforming coastal structures within zoom coastline	Enforce protection law against dive shops; fines + compensatory assessment to repair damaged reef; established new colonies of mangroves, restore coral reefs
Poaching / Damage Prevention	China Coast Guard arresting illegal tour operators in Sanya NMR	No regulatory actions put/taken place	CCTV monitoring of coral reefs; arresting poachers; prohibiting / arresting coral souvenir sellers selling; fines up to 50000 RMB

To better manage its economy and administrative zones, and to mitigate ecological and environmental impacts from tourist growth, Sanya has reorganized the city administration from six townships to four districts in 2015, as presented in Fig. 2. This greatly streamlines the administrative approval process. Sanya is now listed as Hainan Province's strategic fulcrum city for the marine portion of "One Belt One Road" initiative (Wang and Wang-2016).

Recent development: policy and priority changes - pollution reduction

To combat pollution under its 12th Five Year Plan, the city of Sanya advanced its environmental health and tourism infrastructure by completing phase one of its garbage

incineration power plant project, expansion of its domestic waste treatment plant project as well as its kitchen waste treatment plant project. While garbage collection is now more robust, the newly built urban wastewater treatment plant brings the city's sewage treatment capacity from 185,000 tons per day to 225,000 tons per day. A total of 267 km of drainage and sewage pipelines were built, strengthening water pollution treatment (Wang and Wang 2016), as illustrated in Table 1.

A new government policy to unify “policies under one” will help coral reef protection (Feng and Ge 2015). According to Sanya government, the city of Sanya has earmarked 717 million RMB for environment protection and conservation in 2016 (Wang and Wang 2016). 300 million RMB will be spent to strengthen ecological protection and construction, of which 150 million RMB will be for wastewater treatment, i.e. sewer dredging, and maintenance of sewage treatment and water purification plants. The goals are to increase sewage treatment and emissions compliance, thus helping to improve water quality in rivers and seas. The other 417 million RMB are budgeted to enhance public green space management and accelerate construction of tourist toilets. This will support ecological restoration of rivers and coastlines.

In addition to sewage treatment spending, another 5 million RMB will be used to clean up and collect rural solid waste; 17.5 million RMB to promote "Green Island" construction including new tree planting; and 69.5 million RMB are earmarked to subsidize waste incineration power generation project, proper food waste disposal and landfill leachate, strengthening protection of the marine environment and water ecology.

Recent development: policy and priority changes - habitat protection

A report from the provincial Department of Environmental Protection on the newly established One District, One Policy (Feng and Ge 2015) stated that the province will effectively integrate environmental protection, water supply, forestry, marine ecological protection in various sectors, designating land conservation with a total area of 11,535 km². This policy implementation covers a land area of 33.6% of government owned land (national), and for marine waters, marine ecological protection area of about 3,009 km². This is an example of land-sea based coordination that scientists have been advocating for each city district's governance, i.e. land- and sea-based eco-redline zoning laws (Zhang 2010). Within each, the zoning is separated into two: 1) strictly no development; 2) restricted

development. In #1, absolutely no development activities are allowed; in #2, no industrial development, no mining, housing, agriculture or mariculture (Feng and Ge 2015). In an example of how “science informs policy making,” as summarized in Table 2, the press highlights the fact that a scientific systematic review of the province's biodiversity.

Table 2 Summary of how science informs management at Sanya Marine Reserve

	Science informing	Government action	Media reports / results
Pollution	Land- and sea-based pollution must be reduced	Built sewage plants and pipelines; reduced farming & aquaculture impacts	Environmental protection and investments by government reported & highlighted
Habitat Loss	Importance of mangroves as filter and nursery for fisheries	Planting Mangroves zones and habitat; restoring coral reef	Media raising overall awareness; educating public
Poaching / Damage	Monetary & environmental damages by poachers, illegal tour operators, polluters underscored and damages estimated by scientists	Enforcement actions including press conferences, responses to news stories, MPA monitoring, making arrests and imposing fines	Photos and videos included in news reports; posted online and government actions and responses also reported

conservation, soil and water conservation, water conservation and other ecosystem services and ecological sensitivity of coastal zone was used to make policies on coordinated social and economic development planning, town and country planning, land use, environmental planning, and other conflict between industrial development planning. To restore habitats, enforcement of construction project environment laws is clearly underway. Sanya and Hainan governments are tearing down illegal structures, including hotels and office buildings within 200 m of the coastline. To prevent environmental damages that are harmful to

sustainable coral reef and development of marine based tourism, coastal structures within 300 m of coastline will be regulated and permits required for any construction (Shen 2015).

Recent Development: Policy and Priority changes - Restoration and Damage Prevention

At Sanya, coral reef restoration and mangrove reforestation projects are taking place.

According to press reports, the Sanya Municipal Government invested 15 million RMB to restore 70,000 m² of mangrove forests in the Sanya River catchment, and designated Tiedeng Harbor as a mangrove protected area as a nursery to plant and grow 500,000 mangrove trees. This and other projects are unifying and coordinating policymaking and implementation, part of and an example of how science and research in Sanya Nature Marine Reserve is informing policy making (Kuang 2011).

Anti-poaching and human damage prevention are also top priorities. The government is investing regulatory frameworks for preventing illegal tour operators from operating in the Sanya Marine Reserve (Luo 2013). Teams from various Sanya government agencies have joined forces to patrol the protected areas to prevent poaching.

Arrests were made as a result; sometimes with the aid from the media or the installation of surveillance cameras and closed circuit TV monitoring (Yang 2016a). For example, in February 2016, in the Xiao Dong Hai coral reef within the Luhuitou protection zone, a number of poachers were using crowbars to dig “fossil jade” (Wang 2011). Over many days, their actions persisted but were reported by the press. Finally, on 9th March 2016, the Sanya government held a press conference. Sanya Ocean Admin head Mr. Zhang and Sanya City Vice Mayor Li Jing Song jointly announced the arrests of these poachers. Three individuals were each fined 10,000 RMB. On 11th March 2016, a journalist visited shops around Jiefeng Lu walking street in Sanya, noting that “fossil jade” could no longer be purchased. Even the advertising signage - previously very widespread there – had been taken down. Shopkeepers mentioned that none could be purchased, otherwise penalties would apply. In addition, they have recently banned all trade regarding giant clams on the market (Huang 2016). The Sanya government plans to implement long-term measures and is considering proposals to close off areas that have suffered reductions in coral coverage from scuba diving on a rotational basis. Punitive damages are added to statutory fines to further deter poachers and protect the reefs (Yang 2016b).

Discussions, Conclusions and Recommendations

To quantify the effect of how science informs policymaking and management, and how media reporting raises awareness, a number of initiatives ranging from investing in sewage treatment and restoration of coral reef and mangrove are cited as examples in Table 2. In terms of science informing policy makers, it is clear that land- and sea-based pollution must be reduced if coral reef protection is to succeed. Investments in mangrove forest restoration were increased, and economic value of coral reef protection are better understood. Media reporting has brought awareness in environment protection by government, and public education of habitat loss has improved. An increase in patrolling, partly prompted by media reporting, helps prevent poaching. The actions from the scientific community and the media, in reducing pollution, protecting and restoring habitats, and preventing poaching and damage, will be continually assessed.

In conclusion, authorities, on national and local levels, are beginning to recognize that protecting the environment is not just ethical, but also good governance and good business practice. The turning point seems to be the enactment of the 12th Five Year Plan in 2010. New priorities from the central government are percolating to local priorities now.

For a place like Sanya, natural resources are the core of its tourism industry and a balance between economic development and environmental protection and management is critical. Initial signs are observed of turnaround in preserving coral habitat and biodiversity. Science is indeed informing policy making and management. The government and society are seeking a balance between short-term economic benefits and long-term sustainable use of the resources (Zhang 2004).

Hence, there may still be hope for marine conservation and coral reef protection in Sanya before it is too late. For a successful turnaround to occur, we must increase reef monitoring, which has been sparse and uncoordinated. Without systematic monitoring, the status of coral reefs in China will remain poorly understood and the decline in coral cover will be easier to miss, ignore or deny (Hughes et al. 2012). Therefore, to sustain investment in monitoring (via programs like Reef Check), research is needed.

An evaluation of health status of coral reefs is important for the reasonable protection of China's coral reef resources. Traditionally, researchers have conducted basic biological

and ecological research, but few studies were carried out on health assessments of coral reefs (Wu and Zhang, 2012). More is needed to study the repair or recovery of damaged reef ecosystems and begin health assessments. To achieve that, measuring baseline data is very important. More efforts are needed to monitor and understand current spatial distribution and coverage, and decipher baseline conditions of coral reefs in Sanya, such as the age, biodiversity and health status of past, existing, and restored reefs.

From the perspective of MPA designation, one may consider adding onto the current Sanya Marine Reserve with a special marine protected area (SMPA). Previously, Ma et al. (2013) had proposed that setting up SMPAs would be a complementary strategy for supplementing MPAs in China. Establishing SMPAs adjacent to Sanya Marine Reserve would help narrow the gap between conservation and local economic development and could be a consideration as Sanya's next steps.

In sum, our recommendations include:

- Increased staffing for coral reef monitoring and management
- Regular evaluation of coral reef health status
- Collecting baseline data of spatial distribution and coverage of coral
- Establishing further SMPAs adjacent to SMNR
- Implementing harsher penalties (to discourage further breaking of environmental laws)
- Heightened enforcement of SNMR rules and regulations

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